

TWINNING TWO GRADE 11 MATHEMATICS TEACHERS INTEGRATING INFORMATION COMMUNICATION AND TECHNOLOGY IN TEACHING ALGEBRA

ABSTRACT

The purpose of this article is to report on the effectiveness of integrating Information Communication and Technology (ICT) of the twinned teachers in teaching and learning mathematics in the 21st century. Both qualitative and quantitative approaches were used and Valsiner's zone theory of child development was used as lens in understanding the effectiveness of integrating ICT to teach mathematics. The pre-test and post-test were administered to learners in experimental and control groups. Two Grade 11 mathematics teachers were interviewed and 16 classroom observations were conducted, namely: three as baseline observations, ten observations during the interventions and three as post-intervention observations. Data were analysed using the Wilcoxon Rank-Sum test and interpretive paradigm was also used as a tool of analysis. It has been found that one village secondary school performed better than the other did. It has also been found that these schools have poor networks (poor Wi-Fi connections), which contribute to the inaccessibility of materials such as downloading video-clips on YouTube and other materials related to mathematics content, cannot slides during lessons due to broken projectors, cannot access worksheets and handouts being uploaded onto school websites, poor maintenance of ICT tools, theft of ICT equipment and a lack of ICT training for teachers. Benefits of using ICT tools in teaching and learning mathematics are found to be the following: time saving, learning different approaches from the internet, and accessing additional teaching materials (such as videos, worksheets and handouts). It is recommended that mathematics teachers in village schools should be trained to be ICT literate, and that schools contract a technician if possible to maintain the hardware and improve Wi-Fi connectivity.

Keywords: ICT, mathematics education, 21st-century classroom, school twinning

INTRODUCTION

School twinning is described as an important programme that brings two schools together to share their experiences and expertise (Lock, 2011). This article reports on the use of ICT with the twinned mathematics teachers from two schools performed differently. The modern mathematics classroom mainly focuses on transforming teaching and learning, that is, from a traditional to a digital approach (e.g. Krishnasamy, Veloo & Sok Hooi 2014; Jegede, Adeleke, Jegede & Ayanlade 2015). This study sought to report on the effect of incorporating ICTs in the teaching and learning of Grade 11 algebra, to determine whether and how it improved learner performance and affected the teachers' traditional ways of teaching in two schools in the Limpopo province. The study responded to the following questions, which guided the research: (a) What is the effect (or lack thereof) of incorporating ICT tools in the teaching and learning of 21st-century mathematics during twinning? And (b) How has the integration of ICT materials changed teachers' teaching practices?

THEORETICAL BACKGROUND

Valsiner's (1997) zone theory of child development was adapted for use in what has become a technologically oriented world. The theoretical underpinnings in this study draw on research into teacher perceptions and development, particularly in terms of integrating technology in the teaching and learning of mathematics. Teaching mathematics in the 21st- century should be integrated with ICT, but research revealed that many countries still lack access to technology in the teaching and learning of mathematics. Institutional support is vital for ensuring the effective integration of technology in teachers' everyday practice (see Wallace 2004; Hoyles, Lagrange, Son & Sinclair 2006). Thomas (2006) describes factors that hinder the integration of ICT in mathematics teaching, such as lack of access to computers, software or class sets of graphics calculators, teachers' lack of skills and confidence.

The adoption of Valsiner's (1997) zone theory of child development investigates the interactions between teachers, students, technology and the teaching and learning environment. Valsiner describes two additional zones: the Zone of Free Movement (ZFM) (which structures learners' interactions within the learning environment) and the Zone of Promoted Action (ZPA) (which represents the actions of a more experienced or knowledgeable person in helping to promote specific types of learning). When using zone theory to advance teachers' professional learning, the ZFM works beyond the constraints to focus on the school environment (e.g., learners' characteristics, access to resources and teaching materials, and curriculum and assessment requirements), while the ZPA represents opportunities to learn from preservice teacher education, colleagues in the school setting, and upskilling courses or professional development (Bennison & Goos, 2010). When teachers are learners, the ZPD becomes a set of possibilities for development that are influenced by the teachers' existing mathematical and pedagogical knowledge and beliefs. This pedagogical knowledge must include knowing how to successfully integrate knowledge of both content and technology, in order to promote learning. Thomas and Hong (2006) call this "Pedagogical Technology Knowledge" (PTK), and it has been suggested that PTK can be used as a framework by researchers attempting to investigate mathematics teachers' use of technology (Thomas & Chinnappan 2008).

Jegede et al. (2015) conducted a study on how students use the innovation of a tablet of knowledge called *Opon Imo* (a portable, touch-screen Android-powered e-learning device). Their study, which sought to determine the perspectives of teachers and students, made use of questionnaires and content analysis to collect data. Again, Jegede et al. (2015) found that the majority of students (63% to 85%) did not use the tablets for tasks such as reading books, completing assignments, practising past questions or storing important information. Teachers' perspectives on the use of technology in the classroom showed that it was mostly used for watching films and other forms of relaxation.

Similarly, Krishnasamy, Veloo and Sok Hooi (2013) investigated the perception of teachers towards media materials usage in teaching secondary school mathematics. Their findings revealed the effectiveness of media material usage, problems with facilities and infrastructural problems. The study showed that while the use of media materials is important in the teaching of mathematics, such materials must be appropriate and relevant to the subject matter being taught. In support of Krishnasamy et al. (2013), Yusup (1997) advocates that schools should have a media budget allocation for maintaining ICT equipment. In addition, schools require the services of a media computer technician to repair hardware and install and update software.

Consequently, Robertson, Grady, Fluck and Webb (2006) note that the use of media materials in teaching mathematics encourages and motivates learners to learn. Blackmore, Hardcastle, Bamblett and Owens (2003) support the notion that teachers who use ICT tools can motivate learners, encourage creative thinking and facilitate learner understanding. Yusup (1997) adds that the use of media materials increases learner achievement, saves time in teaching and learning, and improves learners' attitudes towards learning mathematics.

Brahim, Mohamed, Abdelwahed, Ahmed, Radouane, Khalid and Mohammed (2014) conducted a study on the advantages of how mathematics teachers use ICT for both teaching and learning. In their North-African study, questionnaires were used to collect data to address the research problem. Their findings revealed that most mathematics teachers use the internet for non-pedagogical purposes (e.g., personal use), therefore in their view, teachers in Moroccan high schools need technical, pedagogical and didactical training about internet use. However, Brahim et al. note that ICT usage encourages active and collaborative learning, facilitates individual learning and modifies the structure of frontal teaching.

The use of ICT resources should be integrated into the process of teaching and learning, according to Lever-Duffy, McDonald and Mizell (2003). This integration in classrooms may not only bring about opportunities for learning and teaching, but is strongly encouraged from within the mathematical and scientific community (Ndlovu et al. 2011). Hamdane, Khaldi and Bouzinab (2013) postulate that ICT is important in this subject field, especially as the integration of ICT can make learning fun, interesting and more effective.

However, the effective integration of ICT into mathematics teaching poses a challenge to teachers (Kilicman, Hassan & Husain Said 2010). Hamdane et al. (2013) identified possible reasons as including resistance (due to a lack of knowledge or skill in the use of new technologies) and difficulty accepting new working methods, or, possibly, questioning the effectiveness of certain technologies. Ndlovu et al. (2011) agree that although teachers who integrate new technologies find it a challenge, they can nevertheless uncover ways of empowering or enhancing learners' mathematical learning. Studies show that the integration of technologies complicates the teachers' teaching practices (see Robert & Rogalski 2005). Therefore, studies have not been done on how alleviate the complication the ICT causes in the teachers' teaching practices. This is the focus of this study to measure the effectiveness of ICT by twinning two teachers teaching Grade 11 algebra in the under-performing school where it was not used during teaching and learning prior twinning process and also to understand how the integration of ICT can change the teacher's own practices in mathematics during twinning.

METHODOLOGY/METHOD

Both qualitative and quantitative approaches were used and Valsiner's (1997) zone theory of child development was used as lens in understanding the effectiveness of integrating ICT to teach mathematics. Data was collected through a pre-test, post-test, semi-structured interviews and classroom observations. The two tests were administered to learners in experimental and control groups, to enable a comparison of their performances. Two Grade 11 mathematics teachers, thus teacher B from performing school and teacher A from the under-performing school, were interviewed and 16 classroom observations were conducted, namely: three as baseline observations, ten observations during the interventions and three as post-intervention observations. Permission to conduct the study was granted by the Limpopo Department of Education. Informed consent was requested of the teachers and learners prior permission had been obtained to conduct the research. Teachers and learners were ensured of confidentiality, voluntary participation and to withdraw at any stage, their names used as pseudonyms and then signed the consent forms.

Examination bank, Grade 11 textbooks and study guides were used to develop the test instrument on algebra, which subsequently underwent quality assurance with two senior academics in the Department of Mathematics Education, and two Grade 11 mathematics teachers with more than ten years' experience. The instrument was also presented in one of the conferences to obtain inputs from peers and other senior academics in mathematics education. The reliability of quantitative results (pre- and post-test) can be gauged according to whether a test yields same results repeatedly. The test instrument was piloted in the school that did not participate in the actual study, to measure the performance of the learners, and the results were similar to those presented by the experimental group. The reliability of the results of this study was measured using Wilcoxon Rank-Sum (Mann-Whitney) test, with the data captured through Microsoft Excel. The statistical data are analysed using the Wilcoxon Rank-Sum test for statistical significance. The Rank-Sum test was used to compare the two study groups. Furthermore, the interpretation was performed at a 95% confidence limit. A possible threat to the validity of this design was that the participants might have remembered the responses on the post-test from the pre-test. However, because of the time gap between the two tests, this situation was probably not applicable to the experimental and control groups.

RESULTS

The findings of this study are analysed separately, thus the qualitative data analysis is done on classroom observations and the teachers' semi-structured interviews, while the statistical data are derived from the implementation of ICT materials in the experimental group. The study was two-fold: the first phase analysed part of the baseline classroom observations with teacher A and teacher B in their respective schools, followed by the findings of the implementation of ICT materials and then the semi-structured interviews. The statistical data analysis follows the quantitative data analysis, which interrogates the findings by measuring the effectiveness of the implementation of ICT materials using the pre- and post-test results of the learners.

Present-day mathematics classrooms have transformed teaching and learning from a traditional to a digital approach (Krishnasamy et al. 2014; Jegede et al. 2015). The findings of this study revealed that teacher A had mostly used the textbook, study guide, chalk and chalkboard when presenting his lesson. This revealed that learners were not engaged with ICT tools to learn mathematics. This impeded the teacher from following the novel approaches being implemented in many 21st-century classrooms around the world. The findings also revealed that a group of learners in the experimental group shared one textbook (as reported by teacher A of the experimental group during the semi-structured interview). For example, '*mo sekolong sa rena re na le bothata ba ditlabakelo tša go ruta (in our school we experience a lack of teaching and learning resources); four to five learners share one textbook*', said teacher A. This revealed that technology in this school showed to have played a marginal role due to lack of resources (Valsiner 1997). The findings in the experimental group were inconsistent with the findings in the control group, as teacher B in the control group followed a 21st-century teaching approach by using DVDs, worksheets and handouts (some downloaded from the internet and others developed by himself).

The integration of ICT materials requires a more experienced or knowledgeable person to promote specific types of learning, in accordance with the ZPA (Valsiner 1997). Teacher B was invited to present lessons using ICT and other materials such as worksheets and handouts to make learning more effective. Teacher B demonstrated to have a sound knowledge of using ICT tools and showed teacher A how to infuse them in the teaching and learning of mathematics. For example, teacher B with the help of teacher A incorporated DVDs into six lessons and gave learners worksheets and handouts to study and solve problems in the other four lessons, especially those dealing with financial mathematics and functions. The teachers asked the learners to pay attention to the DVD lessons, and stopped the lessons if they did not understand a concept. For example, one of the learners asked the teachers to pause in order to obtain clarity on parabola functions taught in lesson 9: '*Sorry Sir, ke kgopela go kwisisa ge re somisa equation $f(x) = ax^2 + bx + c$ le $f(x) = a(x - x_1)(x - x_2)$ (... I want to understand the distinction between the two equations)*'. This concurs with Valsiner's (1997) zone of free movement (ZFM) which structures learners' interactions within the learning environment. The learners appeared to be confused when comparing $f(x) = a(x - x_1)(x - x_2)$ and $f(x) = ax^2 + bx + c$. They found the second equation more straightforward, but they were baffled by the first equation, which they found more difficult. The lessons integrated with DVDs seemed to be effective, as most learners interacted with the teachers, seeking clarification of concepts by asking questions as compared to their participation before the intervention. Teacher A opted to integrate ICT materials in the post ICT intervention during twinning.

The descriptive statistics generated from the pre- and post-test data are discussed in light of the research objectives of the study. As indicated earlier, the statistical data are analysed using the Wilcoxon Rank-Sum test for statistical significance. None of the variables are normally distributed (all *p-values* are below 0.05). The use of a parametric test is warranted due to this abnormality distribution. The Rank-Sum test was used to compare the two study groups. Furthermore, the interpretation was performed at a 95% confidence limit. Two permutations were used to analyse the statistical data, namely the difference between and within the study groups.

The quantitative analysis of the pre-test and post-test results used table 1 representing the learners' performances, which depict the data generated from the experimental and control groups on question 1 (Q1) to question 6 (Q6). The pre- and post-test results are summarised in table 1, and compared per question.

Table 1: Pre-test and post-test results: Wilcoxon Rank-Sum (Mann-Whitney) test

Question	Experimental			Control		
	Pre-test	Post-test	p-value	Pre-test	Post-test	p-value
Q1	1273.5	2467.5	0.0000	1590	1980	0.0805
Q2	1768.5	1972.5	0.3730	1480	2090	0.0060
Q3	1552	2189	0.0050	1443	2127	0.0019
Q4	1491.5	2249.5	0.0009	1572	1998	0.0553
Q5	1099	2556	0.0000	1295.5	2274.5	0.0000

Q6	1376	2279	0.0000	1572.5	1997.5	0.0550
Total rank	8560.5	13713.5	0.0010	8953	12467	0.0460

The results in table 1 show the analysis of the two study groups, between the groups and within the groups in the pre-test and post-test for Q1 - Q6. The experimental group's results showed a significantly different score between the pre-test and post-test ($p - value = 0.0010$), less than **0.05** at a **95%** confidence limit. On the other hand, the control group indicated significant different scores between the pre-test and the post-test ($p - value = 0.0460$) greater than the $p - value$ **0.05**, which suggests no significant improvement when compared to the experimental group, which improved significantly in the post-test. However, the experimental group performed significantly better than the control group in the post-test. The results of the experimental group showed that the learners improved significantly in solving quadratic equations, exponents and exponential equations, financial mathematics and functions. This showed that learning was fun, interesting and effective during teaching and learning (Hamdane et al. 2013).

DISCUSSION OF RESULTS

In post-ICT intervention, it became clear that teacher A had adopted teacher B's method of using handouts and worksheets and integrating ICT materials in teaching his Grade 11 class. The integration of ICT of teacher B during the integration has shown him to have an experience in using ICT tools to teach mathematics. This concur with Valsiner's (1997) zone of promoted action (ZPA) which represents the actions of a more experienced or knowledgeable person in helping to promote specific types of learning. This shows that teacher A was motivated by teacher B's integration of technology when teaching mathematics during the intervention. Krishnasamy et al. (2013) indicate that the availability of resources enhances the effectiveness of teaching; previously, teacher A had used only the textbook and study guide to teach prior the intervention. Subsequent to the intervention, teacher A gave his learners handouts and worksheets to use when discussing problems in class. DVDs were used three times when teaching concepts, which showed that he had been motivated by what teacher B did during the intervention. In fact, teacher A used DVDs for almost 25 minutes of the lesson. While the learners watched, he sometimes paused to allow the learners to solve problems, before the DVD presenter gave the solutions. Teacher A would say, for example: 'Okay, let's see if you can solve this problem $\frac{2}{x+3} \leq \frac{1}{x-3}, x \neq \pm 3$.' Clearly, he had realised the importance of incorporating ICT as an opportunity to improve classroom teaching (Ndlovu, Wessels & De Villiers, 2011).

The analysis of the results in the pre-test and post-test in the two study groups revealed statistical significant different scores for the experimental group ($p - value = 0.0010$) below the $p - value$ 0.05 at a 95% confidence limit. On the other hand, the control group also showed a statistical significant difference in the pre-test and post-test ($p - value = 0.0010$) below the $p - value$ 0.05 at a 95% confidence limit. The results revealed that the two study groups improved significantly in the post-test, suggesting that the learners improved generally in solving Grade 11 algebra. Although the two study groups both improved significantly, the experimental group yielded a greater improvement in the learners' performance in Grade 11 algebra, when compared to the control group. The results suggest that the ICT intervention had a positive impact on Grade 11 algebra in the experimental group. The results also suggest that the integration of ICT amplified the complexity of mathematical content (Lagrange & Monaghan, 2009).

CONCLUSION

The results reveal that both groups improved significantly in the post-test, suggesting that the learners generally improved their skills in solving Grade 11 algebraic problems. Although both groups improved significantly, the experimental group yielded a greater improvement in terms of the learners' performance in Grade 11 algebra than the control group. The results suggest that the intervention (which integrated ICT materials in teaching algebra) had a positive impact on the experimental group. Furthermore, teacher A was encouraged to use pedagogical knowledge that must include knowing how to successfully integrate knowledge of both content and technology, in order to promote learning during twinning process. This study recommends that mathematics

teachers be given training on how to integrate ICT materials in the teaching and learning of mathematics, as it will allow them to improve and invigorate their lessons. The research indicated that learners are indeed digital natives, thus teachers should become more skilled in using ICT materials, if they are to cope with the demands of 21st-century learners.

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